Long-term Monitoring of Active Galactic Nuclei with Swift

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Abstract: We will present long-term X-ray and Ultra-violet/Optical light curves of four Active Galactic Nuclei (AGN) observed with the NASA Neil Gehrels Swift Observatory. These four AGN (QSO 0056-36, Fairall 1116, CBS 126, Mkn 876) represent different classes of AGN with different black hole masses and accretion rates. We will discuss the variability of the X-ray and UV light curves of these AGN and how they correlate to the black hole mass and accretion rates.

I. Introduction: Dr. Grupe's eight-person research team has been using the NASA Neil Gehrels Swift satellite (Gehrels et al. 2004) to analyze long-term variability data including X-ray and ultraviolet emissions which allow us to make light curve graphs for our AGN sources. Swift has been in use for more than 14 years, which means that we have extensive observation data for all of the 110 AGN sources that we are analyzing. Long-term variability data means we can see trends in how AGNs have changed over long periods of time, and use this data to determine causes for the changes in emissions from these sources, whether it's from accretion rate changes, absorption, or reflection. Additionally, all of the analyzed sources are from either broad or narrow line Seyfert 1 galaxies. The method of identification utilizes the optical spectra which are present for each source. Figure 1 shows a model of an AGN and its various parts.

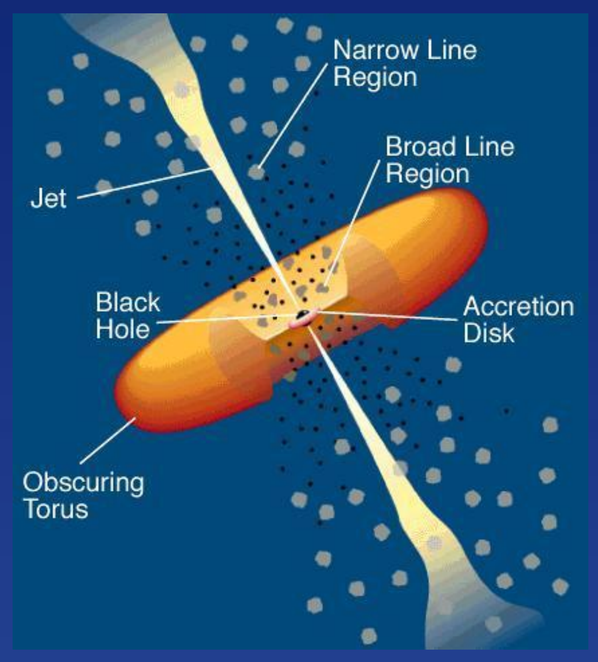

figure 1: Model of an active galactic nucleus (Urry, Padavoni et al. 1995). The model shows the accretion disk and the black hole, two things we are concerned with measuring here. The areas marked "narrow line region" and "broad line region" determine which type of Seyfert galaxy we are observing. The jet is a stream of material given off by the AGN, and, along with the obscuring torus, can affect how we view these stellar objects. AGNs are especially notable compared to other objects because they are the brightest sources of electromagnetic radiation that we can observe.

II. MKN 876: Makarian 876 is a broad line Seyfert 1 source, seen in figure 2, whose observation data goes back 12 years. This makes it a prime candidate for demonstrating the capability of Swift's long term variability data. The light curve for MKN 876 is displayed in figure 3. This data shows that it has steadily declined in UV emissions during its observation period. It is unknown why the x-ray emissions for this source have increased during the observation period, as it was expected that they would decrease alongside the UV. This increase in x-rays would suggest that the AGN has an increasing accretion rate.

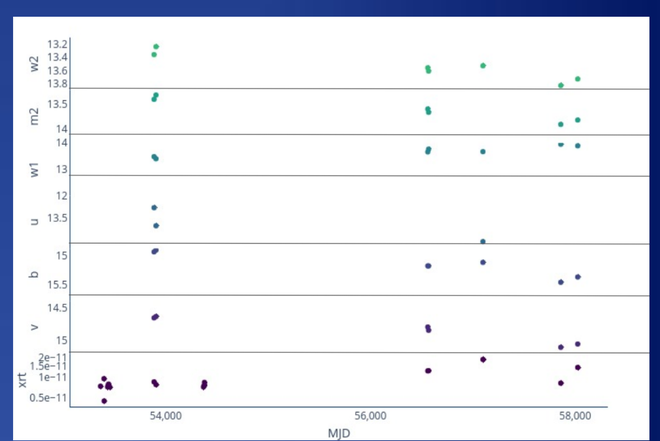

figure 3: Swift XRT and UVOT Light curves of MKN 876

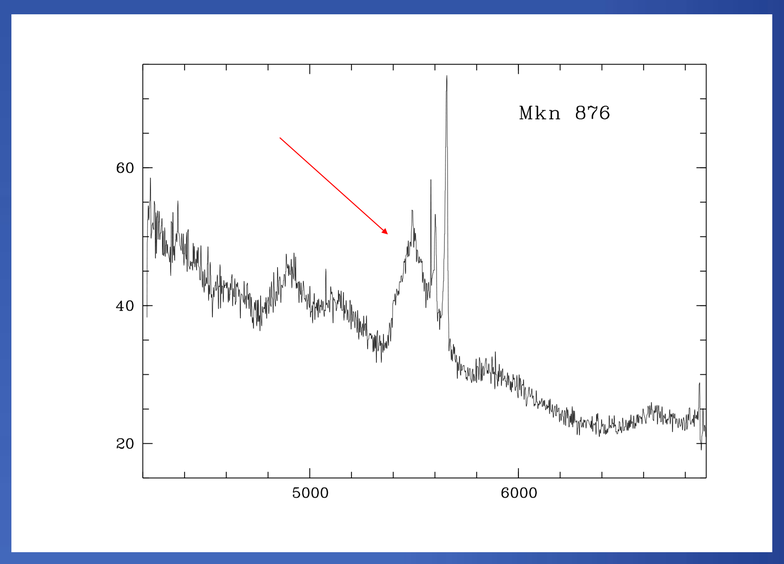

figure 2: Swift optical spectrum for MKN 876. The h-beta line that identifies the source as a BLS1 is indicated with an arrow.

III. CBS 126
CBS 126 is a narrow line Seyfert 1 source, shown in figure 4, that is radio quiet. Like MKN 876, 12 years of observation data is available. The light curve for this source, shown in figure 5, indicates that it is a relatively constant source, showing only a slight decrease in UV and X-Ray emissions during its observation period. This could mean a decreased accretion rate, or potentially an absorption period during which a gas cloud moved in front of the source, obscuring some of the emissions we receive from the source.

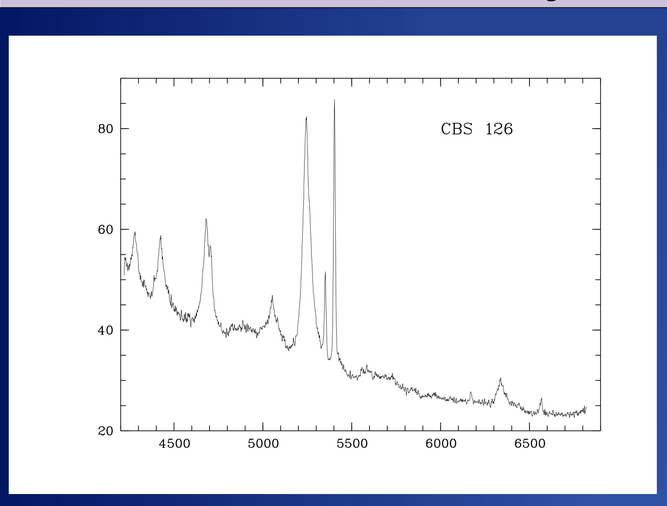

figure 4: Swift optical spectrum of CBS 126

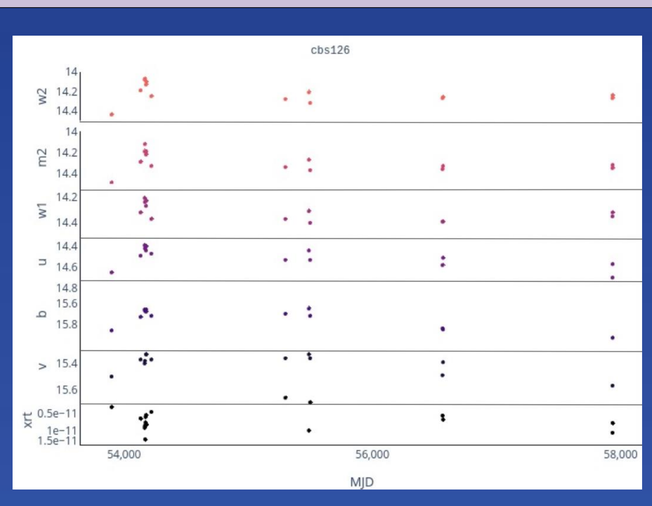

figure 5: Swift XRT and UVOT Light curves of CBS 126

IV: QSO 0056-36
QSO 0056-36 is a quasar from a narrow line Seyfert 1, as shown by the optical spectra of QSO 0056-36 shown in Figure 6. The light curve for this AGN source is displayed in Figure 7. Because of an issue with the Swift satellite at the time of observation, UV data was not available for the entire observation period. A spike is still visible in UV emissions during the observation period where we have data for it, suggesting an increase in accretion rate for the supermassive black hole in the AGN.

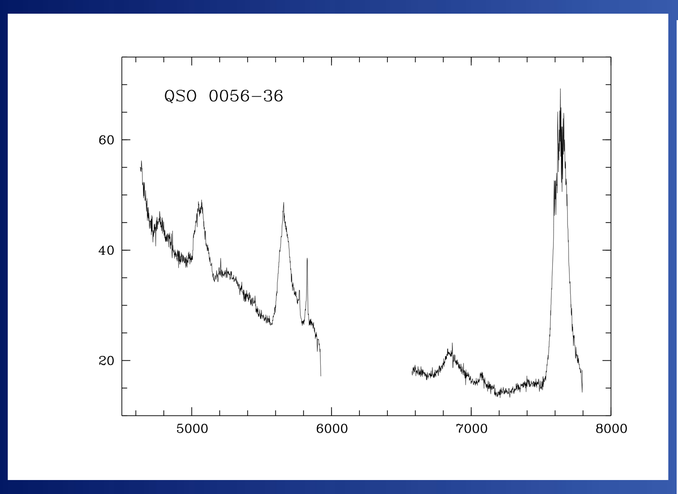

Figure 6: Optical spectrum of QSO 0056-36

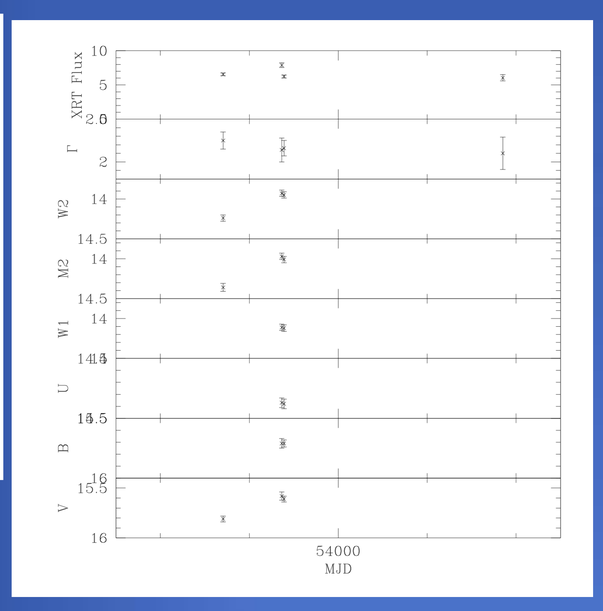

Figure 7: XRT and UV light curve of QSO 0056-36

V. Long Term Variability Data and Swift's Other Advantages
One of Swift's biggest advantages as seen in all of the light curves is that a very long window of observation can be seen. This is the long-term variability data that allows us to get a better idea if a decrease in XRT and UVOT emissions are caused by absorption, reflection, or a decrease in accretion rate for a given supermassive black hole. Another capability of Swift is how quickly it can get data on a given source. The name Swift is not an acronym and instead references the ability of the satellite to even observe a source multiple times per day. Depending on how high of a priority a request for an observation of a given source is, the satellite can make the observation in only two hours. Figure 8 shows how this data can be used to observe spikes for highly variable sources and the resulting light curve that can be created, as the data here is all within the same year, as opposed to the 10+ year observation periods for the other light curves displayed here.

References:
Grupe, D., et al., 2010
Gehrels et al. 2004
Urry, Padavoni et al. 1995

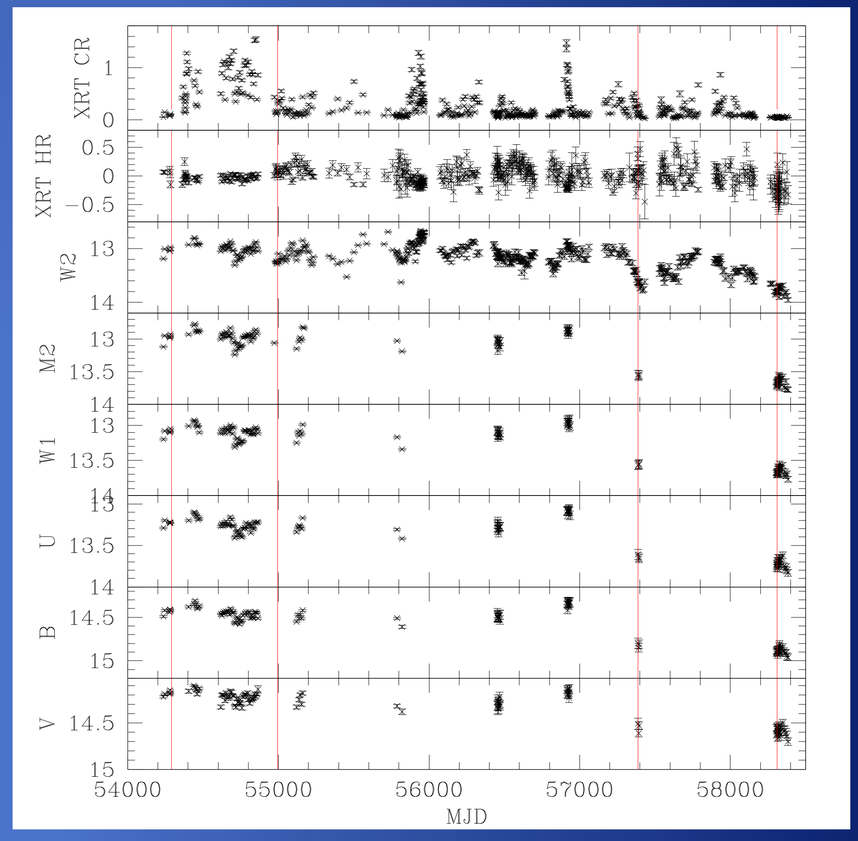

Figure 8: Mkn 335 Swift XRT and UVOT light curves from 2007 - 2018